V. Zhuikov, Dr. Eng. Sc., Prof.
K. Osypenko, Cand. Sc. (Eng.), Assoc. Prof.
National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute»

PRINCIPLE OF PREEMPTIVE CONTROL IN SMART GRID

The necessity of implementing the principle of preemptive control in the Smart Grid is shown. It is mentioned that fea-tures of centralized, decentralized and combined control are based on the Heisenberg uncertainty principle, principle of synergetic development and principle of cognitive control. Five hierarchy levels of control with control objects and strategies are described. Social and personal aspects of preemptive control formation are studied. Main steps of preemptive control are shown.

Keywords: cognitive control, distributed generation, Heisenberg uncertainty principle, preemptive control, Smart Grid.

Introduction

Distributed generation, as part of the trend of world development and evolution of the energy base of Smart Grid, becomes a clearly defined independent and, in many cases, the only possible solution to provide electric energy to separate social and socio-geographical entities [1]. The technical level of implementation of energy and information platforms of Smart Grid depends on the covered space, climatic conditions, the number and density of population, which quality of life, in its turn, is directly determined by the amount of electric energy per one person, as well as by the efficiency of system operation. The vivid illustration of the future of such systems is reflected in the proposal of Stan-ford University employee Mark Jacobson – to transfer 20 million New York State on renewable energy sources [2]. This results in sufficient backgrounds for the development of Smart Grid and Micro Grid.

The community of many individuals, who are both owners and users of independent technical components of the distributed generation system, raises questions for the individual members of the community and the community in general, on solution of which depends not only the well-being, but also the existence of a new socio-technical system, namely:

1) what are the directions of development and transformation of the community, based on a single fully inclu-sive energy and informational platforms, or the society with the "internet of all with energetic of all for all"?

2) what is the effect on the individual and community development of the necessary for their existence and permanent energy and information environment, in which individuals, socio-economic, socio-technical and other social groups exist?

3) what are the features of the distributed generation system control structure and process, which is the basis of the "electricity market" that is active in the energy and information environment?

4) which indicators determine the status and direction of society development, the uniting base of which is the aggregate and individual ownership of energy platform, as well as aggregate and individual participation in the energy distribution and exchange, which is a determining factor in ensuring the prosperity and well-being of community mem-bers?

Structuring the community, that is built on a common energy and information platform, is based on the formation of some of the socio-technical groups with double structure – human and associated energy and information platform – are considered both – as a resource and as a factor in the formation of the community that directly determines the necessity of implementing the principle of preemptive control in distributed generation systems.

Control systems aspects of construction and levels of the hierarchy

Energy and informational community platform creates the necessary conditions for the formation of structures and relationships that are adequate to this platform. Sufficient conditions for the functioning of the system as a whole are determined by the presence of the distributed in time and space control system that puts in accordance with each other the order of interaction of hierarchical technical and social system structures; determines the sequence of actions; carries out the selection of decision-making objectives, criteria and methods. Due to its global property the system organically integrates and implements centralized, decentralized and combined control [3]. Three mentioned principles of control implementation are based on the following aspects.

First of all, it is the **Heisenberg uncertainty principle** [4] that regarding to the physical phenomena indicates the impossibility of arbitrarily precise time-frequency representation of the signal. The action of the

Heisenberg princi-ple points to the limited accuracy of decision making and the possibility of errors accumulation during the prolonged operation, which determines the need to create specific control actions that minimize the negative phenomena.

Secondly, it is the **principle of synergetic development**. The concept of the synergetic structure in relation to the social and technical community is considered as a condition that occurs as a result of multivariate and ambiguous behavior of multi-structures and/or multifactorial environments, which determines the need to generate control actions, ensuring the formation of the positive direction of community development vector and elimination of negative phe-nomena and the prevention of accidents.

Thirdly, it is **the principle of cognitive control**. As a consequence of the above-mentioned duality property of constituting community the participation of the individual in the formation and development of social groups based on its cognitive, mental and emotional qualities simultaneously defines its role in the formation of market relations, the object of the action of which are the volume and the quality of the generated, exchanged and used: 1) energy; 2) in-formation; 3) copyright. This necessitates the implementation in the control structure the laws of cognitology that combines the theory of knowledge, psychology, artificial intelligence, and other aspects related to accumulation and implementation of the knowledge [5].

In the distributed generation systems marked aspects define the logic of construction and operation of general control, wherein five levels of hierarchy are identified (Table 1).

The first level corresponds to the separate systems of generation, distribution, conversion and storage of electric energy state control. Control systems at this level set operation algorithms of power equipment, providing the required parameters of electric energy.

Table 1 – five levels of hierarchy are identified

Hierarchy levels		Control object	Control strategy
5	Preemptive control	Big and small Smart Grid, smart houses	State control of the nodes, connections, tariffs, prohibition on decision making
4	Big data and context-aware control	Big Micro Grid systems as a part of bigger system	Decision making about state of nodes, connections, tariffs
3	Context-aware control	Smart houses, Micro Grid	Decision making about operation modes, reference values, comfort level
2	Centralized and decentralized control	Systems of converters of electrical energy parameters	Operation modes, parameters, stability control
1	Centralized control	Converters of electrical energy parameters	Reference values control

The **second level** corresponds to control of a group of commonly operating power devices included in the sys-tem with a multi-loop feedback, defining operation modes, look of external load characteristics and stable operation conditions of the system while maintaining the specified parameters of electric energy on the load with the required comfort level.

The **third level** of hierarchy corresponds to the application of context-aware control system. This system is based on the application of: 1) microprocessor control systems; 2) stream processing methods; 3) operational applica-tions; 4) smart sensors of electrical parameters, primary energy flows, environment and habitat. Such control systems are implemented, provided the integration of electricity transfer systems and information systems that provide energy and information interaction platform, creating a Smart Grid technology.

The construction of control systems of the **fourth level** is based on the joint application of the theory of big data, context-aware control and installed operational applications designed for efficient use of energy and the stable operation of the whole system [6]. With this the knowledge of person that makes decision is used indirectly and imple-mented in the installed operational applications with subsequent adjustment as a result of the accumulation of knowledge about current social and technological processes.

However, with the presence of multivariate solutions cluster, the synergy and the cognitivity of the system, the chosen solution can lead to positive as well as negative, catastrophic development status of Smart Grid. The countering to negative phenomena is achieved by using a control system, located on the **fifth level** of hierarchy, which imple-ments the principle of preemptive control. The preemptive control concept, used in 2002 in the text of National Strate-gy Security of the United States, is effective when applied to the control of the complex structure of social and tech-nical community with the implementation of new relations, based on the concept of "Internet of all with energy for all". When applied to the considered control the actions of the system are reduced to the following steps:

1) change and/or installation of a new operation mode of interaction of the third and fourth hierarchy levels on the generation, exchange and accumulation of energy;

2) formation at these levels new communications and relations with the inclusion of new operational applica-tions;

3) achievement of sustainable relations based on new and revised operational applications and interaction rules.

If during the further operation the system approaches the critical point, preemptive control repeats steps 1 – 3, implementing in advanced way the elimination of the threat of the destruction of the system, and the localization of technical objects, generating the threat.

The social aspect of preemptive control formation

From the point of social structure the entire community, consisting of separate interacting socio-technical structures, should meet certain requirements, which include: 1) the presence of a limited area of existence of the com-munity, which is determined by the common energy platform of distributed generation system; 2) the community ownerships their own system of social and technical control; 3) the formation of a new establishment history, that is inherent to this exact community; 4) the formation of a new community structure based on energy, information, eco-nomic and cognitive transactions; 5) the possibility of increasing the community human resource with increasing level of power generation or increasing the proportion of the relative energy per one person; 6) the development of their own financial and property markets based on the generation, storage, exchange, sale and purchase of energy of distributed generation systems.

Any actions on changing the current state of the system should start with the first step – confirmation of the authority of subject, who is about to make such actions. If there is no confirmation the preemptive control system blocks the proposed technical changes, perceiving them as a threat, and selects the most stable version of the system structure, prohibiting for some time any other actions, performing specific technical task of maintaining the system integrity and working capacity. After the confirmation of authority the second step is following – the evaluation of the proposed technical changes in modes and connections. After selecting the technical solution the third step is following – signing up the contracts. The confirmation of the signed contracts allows passing to the fourth step – the change in the technical state of the system, passing to new generation modes, new connections, and new terms of energy accu-mulation. On the fifth step the verification of the system stability and fixation of its state for a certain time interval, allowing fulfilling the terms of contracts, is implemented. The collection of information about the formation of new contracts is made on the sixth step. The process is repeated in a cycle from the first step. With this energy and infor-mation platforms of the entire system must meet the requirements of the community in the implementation of their needs of physiological comfort and financial well-being.

By establishing on the **first** step a new interaction mode, the preemptive control, using formulated by Elinor Ostrom [7] the basic principles of stable control of local resources, artificially forms the community structure and gives the first "impulse" for the beginning of commercial activity of "energy market", preemptivly indicating some of the social, legally appointed groups and built community structures.

The **second** step of preemptive control – the formation of new connections and relations on the third and fourth control levels – can be implemented given that the technical level of power electronics devices is compliant to the possibility of implementing the decisions of problems of these levels, as well as to the possibility of implementing the decisions of problems of preemptive control. Furthermore on the second step power electronics devices should en-sure the execution of requirements on small-scale production development, which is formed due to the natural struc-ture of distributed generation and it's belonging to the technical systems of limited power and respectively to the limited financial volume of wide range of owners.

The **third** step – achieving the stable relations – also cannot be implemented without ensuring the system technical capacity. This determines the need: firstly, to form the Micro Grid with concentration devices and the pres-ence of energy connections with neighboring distributed generation systems; secondly, to ensure the required quality of energy; thirdly, to ensure stability of the system; fourth, to ensure the comfort and the ability to act on the "electricity market" for independent Micro Grid, based on context-aware control algorithms; and fifth, to control by using big data to ensure delivery reliability and efficiency of sales and purchases of energy of the entire community.

The personal aspect of preemptive control formation

The principle of control cognition, based on the actions and knowledge of individuals that affect the process of functioning and development of the system and its structure indirectly through operational applications and directly by the decision-making in the operating process, reflects the duality property of individuals as a system resource and as a factor of influence. The last, depending on the actions, the capacity and capabilities of each of the individuals in a certain synergetic association of actions and capabilities enables the evolution of the knowledge of the entire system. No matter to which aspects of the system functioning the actions of individuals were applied, their level of influence on the system depends on such defining personal qualities in this aspect, as: 1) the intellectual level; 2) the level of self-esteem; 3) field independence; 4) the level of professional training. A priori, is understandable that not all knowledge carriers are pursuing socially positive purposes, although knowledge about the negative actions and their consequences are the positive result, and therefore the complete elimination

of the negative actions is nor undesirable, but impossible. The most difficult for fixation and localization are those individuals, who have all four personal qualities of high level. Negative or criminogenic to community behavior is activated by such motives as: 1) hypertrophied claims of a materi-al nature; 2) the need to express negative emotions; 3) hostility to anything specific; 4) social exclusion; 5) legally inad-equate stereotypes. These motives, in one way or another, are related to the emotional state of the individual [8].

In the case of critical points appearance, the preemptive control as a system of the highest level by implementing the first step of control:

- **firstly**, blocks the nodes that are posing a threat to the integrity of the entire system, by disconnecting them from the control of systems of the third and fourth levels, maintaining the control of systems of the first and second levels, but specifying the impacts, indicating thereby the specific operating modes of converters and, respectively, gen-erators, and tariffs of sale and purchase of energy. These features may be delegated to the converters control systems for quicker blocking of destabilizing decisions at the local level;
- **secondly**, if necessary, changes the structure, imposes certain communication tariffs, the way of energy trans-fer, leaving some non-hazardous zone for variation of these parameters for obtaining the information on evaluation of the process development;
- **thirdly**, continue to the next control steps.

Actions on other methods of localization, assessing the level of danger and impact on the node, that provoke active actions of preemptive control, do not belong to a technical the area.

Conclusions

Thus, the implementation of the principle of preemptive control in the construction of big and small Smart Grid on the stages of forming the energy and information structure, control of the status of individual objects and tar-iffs in the system, taking into account the social and personal aspects of the community of individuals formation en-sures the stable operation of such systems.

References

1. I. Dumitrache, D. I. Dogaru, “Smart Grid Overview: Infrastructure, Cyber-Physical Security and Challeng-es,” presented at the 20th Int. Conf. on Control Systems and Computer Science (CSCS). Bucharest, Romania, May 27-29, 2015.

2. M. Z. Jacobson, M. A. Delucchi, G. Bazouin, M. J. Dvorak, R. Arghandeh, Z. A. F. Bauer, A. Cotte, G. M. T. H. de Moor, E. G. Goldner, C. Heier, R. T. Holmes, S. A. Hughes, L. Jin, M. Kapadia, C. Menon, S. A. Mullendore, E. M. Paris, G. A. Provost, A. R. Romano, C. Srivastava, T. A. Vencill, N. S. Whitney, T. W. Yeskoo, “A 100% wind, water, sun-light (WWS) all-sector energy plan for Washington State,” Renewable Energy, vol. 86, pp. 75 – 88, – Feb. 2016.

3. M. A. Aminu, K. Solomon, “A Review of Control Strategies for Microgrids,” Advances in Research, vol. 7(3), pp. 1 – 9, May 2016.

4. W. Z. Heisenberg, “Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik,” Zeitschrift für Physik, vol. 43, iss. 3, pp. 172 – 198, March 1927.

5. L. Shuhui, F. Xingang, I. Jaithwa, E. Alonso, M. Fairbank, D. C. Wunsch, “Control of Three-Phase Grid-Connected Microgrids using Artificial Neural Networks,” in Proc. of the 7th International Joint Conference on Compu-tational Intelligence, 58-69, 2015, Lisbon, Portugal.

6. E. V. Verbitsky, A. G. Kyselova, K. S. Osypenko, “Context-aware control of autonomous power supply sys-tems,” Kyiv, Ukraine: Avers, 2015, 187 p. (Ukr.)

7. E. Ostrom, “Governing the Commons: The Evolution of Institutions for Collective Action,” Cambridge Uni-versity Press. ISBN 0-521-40599-8, – 1990.

8. A. V. Kyrylenko, “Smart Grid in perspective of a systematic methodology,” Works of Institute of Electrody-namics of National Academy of Science of Ukraine, special iss., – pp. 63-72, – June 2011. (Rus.)

УДК 621.314

В.Я. Жуйков, д-р техн. наук, проф.
К.С. Осипенко, канд. техн. наук, доц.
Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського»

ПРИНЦИП ПРЕЕМПТИВНОГО КЕРУВАННЯ У SMART GRID

Показана необхідність реалізації принципу преемптивного керування в Smart Grid. Відзначається, що особливості централізованого, децентралізованого та комбінованого керування засновані на принципі невизначеності Гейзенберга, принципі синергетичного розвитку та принципі когнітивного керування. Описано п'ять ієрархічних рівнів керування з об'єктами та стратегіями керування. Досліджуються соціальний і особистісний аспекти формування преемптивного керування. Показані основні етапи преемптивного управління.

Ключові слова: когнітивне керування, розосереджена генерація, принцип невизначеності Гейзенберга, преемптивне керування, Smart Grid.

Список використаної літератури

1. I. Dumitrache, D. I. Dogaru, "Smart Grid Overview: Infrastructure, Cyber-Physical Security and Challenges," pre-sented at the 20th Int. Conf. on Control Systems and Computer Science (CSCS). Bucharest, Romania, May 27-29, 2015.

2. M. Z. Jacobson, M. A. Delucchi, G. Bazouin, M. J. Dvorak, R. Arghandeh, Z. A. F. Bauer, A. Cotte, G. M. T. H. de Moor, E. G. Goldner, C. Heier, R. T. Holmes, S. A. Hughes, L. Jin, M. Kapadia, C. Menon, S. A. Mullendore, E. M. Paris, G. A. Provost, A. R. Romano, C. Srivastava, T. A. Vencill, N. S. Whitney, T. W. Yeskoo, "A 100% wind, water, sun-light (WWS) all-sector energy plan for Washington State," Renewable Energy, vol. 86, pp. 75 – 88, Feb. 2016.

3. M. A. Aminu, K. Solomon, "A Review of Control Strategies for Microgrids," Advances in Research, vol. 7(3), pp. 1 – 9, May 2016.

4. W. Z. Heisenberg, "Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik," Zeitschrift für Physik, vol. 43, iss. 3, pp. 172 – 198, March 1927.

5. L. Shuhui, F. Xingang, I. Jaithwa, E. Alonso, M. Fairbank, D. C. Wunsch, "Control of Three-Phase Grid-Connected Microgrids using Artificial Neural Networks," in Proc. of the 7th International Joint Conference on Compu-tational Intelligence, 58-69, 2015, Lisbon, Portugal.

6. Вербицький Є.В., Кисельова А.Г., Осипенко К.С. Контекстно-залежне керування автономними системами електроживлення: під загальною редакцією д.т.н. Жуйкова В.Я. – К.: Аверс, 2015. – 187 с. (Ukr.)

7. E. Ostrom, "Governing the Commons: The Evolution of Institutions for Collective Action," Cambridge Uni-versity Press. ISBN 0-521-40599-8, – 1990.

8. Кириленко А.В. и др. Смарт-грид в ракурсе системной методологии // Праці Інституту електродинаміки Національної академії наук України. Спец. випуск. – 2011. – С. 63 –72. (Rus.)

УДК 621.314

В.Я. Жуйков, д-р техн. наук, проф.
К.С. Осипенко, канд. техн. наук, доц
Национальный технический университет Украины «Киевский политехнический институт имени Игоря Сикорского»

ПРИНЦИП ПРЕЭМПТИВНОГО УПРАВЛЕНИЯ В SMART GRID

Показана необходимость реализации принципа преэмптивного управления в Smart Grid. Отмечается, что особенности централизованного, децентрализованного и комбинированного управления основаны на принципе неопределенности Гейзенберга, принципе синергетического развития и принципе когнитивного управления. Описаны пять иерархических уровней управления с объектами и стратегии управления. Изучены социальный и личностный аспекты формирования преэмптивного управления. Показаны основные этапы упреждающего управления..

Ключевые слова: когнитивное управление, распределенная генерация, принцип неопределенности Гейзенберга, преэмптивное управление, Smart Grid.

Надійшла 26.06.2017
Received 26.06.2017